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Big River Benthos: Linking Year-Round Biological Response to Altered Hydrological Regimes

*by Audrey B. Harrison, Clifford A. Ochs, William T. Slack,
and K. Jack Killgore*

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Photo Credit: Freddie Pinkard, Vicksburg District.



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BACKGROUND: The Mississippi River is heavily relied upon for commercial navigation, but it is also home to a diversity of organisms adapted to large river habitats. Macroinvertebrates have long been used as habitat/water quality indicators in wadeable streams, but because of sampling difficulty, large rivers have been understudied. Herein, the authors focused on the benthic macroinvertebrate fauna as indicators of biological response to anthropogenic alterations to flow — particularly to closure dikes — within naturally occurring secondary channels of the Lower Mississippi River. During mid to high river stages, water flows over dikes into secondary channels, but during low river stages, many side channels become disconnected from the main channel at the upstream end. Nine secondary channels spanning a gradient of hydrological connectivity to the main river channel at low river stages were assessed. Main and secondary channels were sampled for benthic macroinvertebrates in May and June 2014 using a Ponar grab and benthic sled, respectively. The objective was to determine whether temporary hydrological disconnection from the main channel during low river stages had a legacy effect on benthic community structure in the succeeding year. There was a significant positive relationship between taxonomic richness in 2014 and hydrological connection of secondary channels in the previous year (2013), indicating a legacy effect of connectivity on macroinvertebrate diversity of secondary channels. These findings contribute to a better understanding of ecological response to altered flow regimes and help document benefits of restoring connectivity between secondary channels and the Mississippi River main channel.

INTRODUCTION: The Mississippi River has undergone many changes in morphology and function over the last two centuries. Human modification of the Mississippi River and its floodplain dates back to the 1700s, when the French settlers began constructing levees to prevent flooding in and around New Orleans, Louisiana (Morris 2012). The Mississippi River Commission, — established in 1879 — was tasked with increasing navigation and commerce, as well as with preventing flooding of the vast alluvial floodplain, commonly known today as the Mississippi Delta (Baker et al. 1991). Modifications of the flow and function of the Mississippi River have only increased since then — markedly so after the Great Flood of 1927, an event that impelled Congress to pass the Mississippi River and Tributaries Project, overseen by the US Army Corps of Engineers. This project included the Channel Improvement Program (CIP) (Killgore et al. 2014). The CIP is responsible for maintenance of a navigable channel along the Mississippi River through the use of river training structures such as revetments and dikes, which maintain channel width and depth, respectively (Killgore et al. 2014). An example of these structures is a series of closure dikes, which are usually placed in the upstream reach of a naturally occurring secondary channel (Figure 1). Closure dikes deflect water flowing into secondary channels around an island into the main river channel. The excess flow aids in maintaining channel depth for commercial navigation and reduces the need for dredging of the main channel during low water stages. When the river stage drops below the elevation of the closure dikes or below sandbars that form around them, secondary channels become disconnected from the main channel at the upstream end, resulting in a series of isolated pools or a completely dry channel bed (Figure 1 – a). In 2006, the Lower Mississippi River Conservation Committee (LMRCC) began restoring flow to secondary channels at low water stages by cutting a U-shaped notch in some closure dike(s) (Figure 1 – b). The authors assume that reduced flow (or complete loss of water) impacts aquatic biota in naturally occurring secondary channels, but the long-term ecological response to this temporary loss of habitat connectivity, or the mitigation thereof, is unknown.



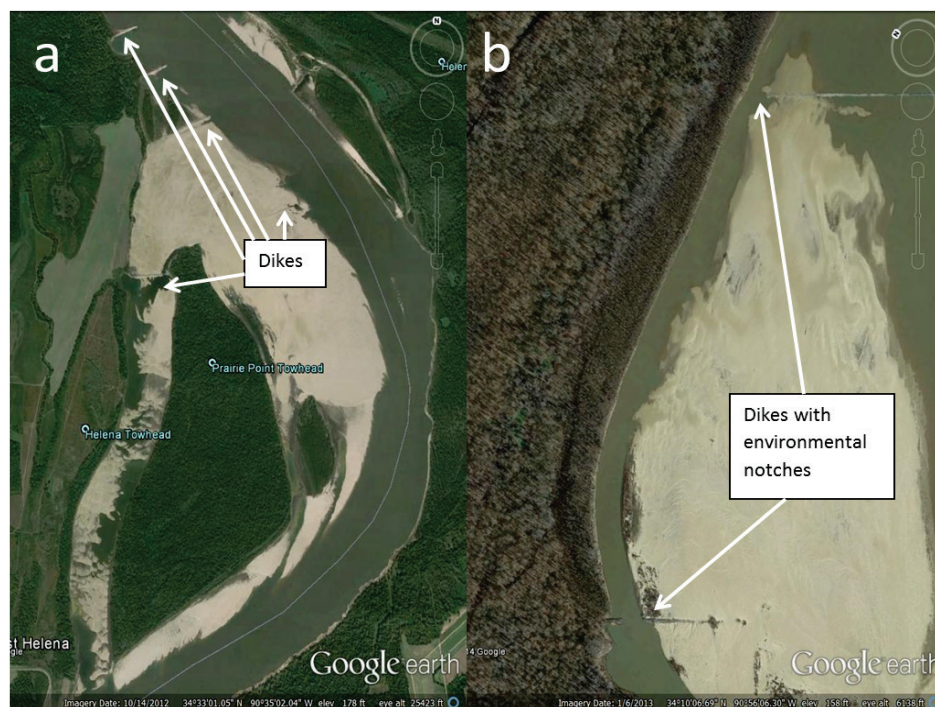


Figure 1. Aerial photographs of (a) Prairie Point Secondary Channel dike field, and (b) Ludlow Secondary Channel dike field; both dikes with environmental notches constructed by the Lower Mississippi River Conservation Committee (LMRCC).

MATERIALS AND METHODS: Nine secondary channels along a 58-mile reach of the Lower Mississippi River (river mile 610 – 668) were chosen for analysis of benthic macroinvertebrate community structure during May and June 2014 (Figure 2). These secondary channels span a gradient of hydrological connectivity to the main river channel (Figure 3). Degree of connectivity was quantified as the river stage at which each secondary channel became disconnected from the main river channel. This stage was determined by the height of the highest elevation of the controlling dike or dike notch for each channel, taking into account the low water reference plane at the Helena, AR, gage. For example, for a particular secondary channel, the lower the height of the highest controlling dike, the greater the connectivity. Controlling dike elevations, retrieved from the US Army Corps of Engineers Memphis District Master Plan, were then plotted against the hydrograph from July 2013 to July 2014 to show when each channel became disconnected and for how long the channel remained disconnected (Figure 3). Historic gage data were obtained from <http://www.rivergages.com>.

Six benthic samples were taken at each secondary channel site using two different gear types: Ponar grab (May) and a “benthic sled.” The benthic sled is a novel gear type for macroinvertebrate sampling. It was originally designed for capture of freshwater mussels (Miller et al. 1989), and for this study it was modified with 540 μ m mesh netting to capture much smaller macroinvertebrates. The main channel was also sampled in three locations (1 location in May, n=6; 2 locations in June, n=18) as a control (i.e., always connected). The Ponar grab (22.86 cm²) was deployed and retrieved



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using a windlass upon hitting substrate. The benthic sled (46 x 20 cm) was deployed, allowed to briefly rest on substrate, pulled until full (<50 ft), and retrieved using a windlass. Upon retrieval, sediments were immediately subsampled (generally 8 L for benthic sled samples), elutriated with river water at least five times or until all organic matter was removed, and sieved through a 500 μ m mesh sieve. Sieved material was then placed in Whirl-Pak® bags, preserved with 80% EtOH, and returned to the ERDC Fish Ecology Laboratory in Vicksburg, MS. Macroinvertebrates from each sample were isolated, counted, and identified to genus-level when possible using an Olympus SZ dissecting microscope and appropriate taxonomic keys (Merritt et al. 2008, Epler et al. 2001), and preserved in 80% EtOH, with the exception of Chironomidae larvae, which were slide mounted with CMCP-10 and identified using a Nikon Labophot-2 compound microscope. Data were compiled and analyzed using Microsoft Excel. Abundance refers to total counts of individuals per volumetric subsample. Species richness refers to counts of individual taxa in each sample.



Figure 2. Study area (RM 610-668). Collection sites in green.



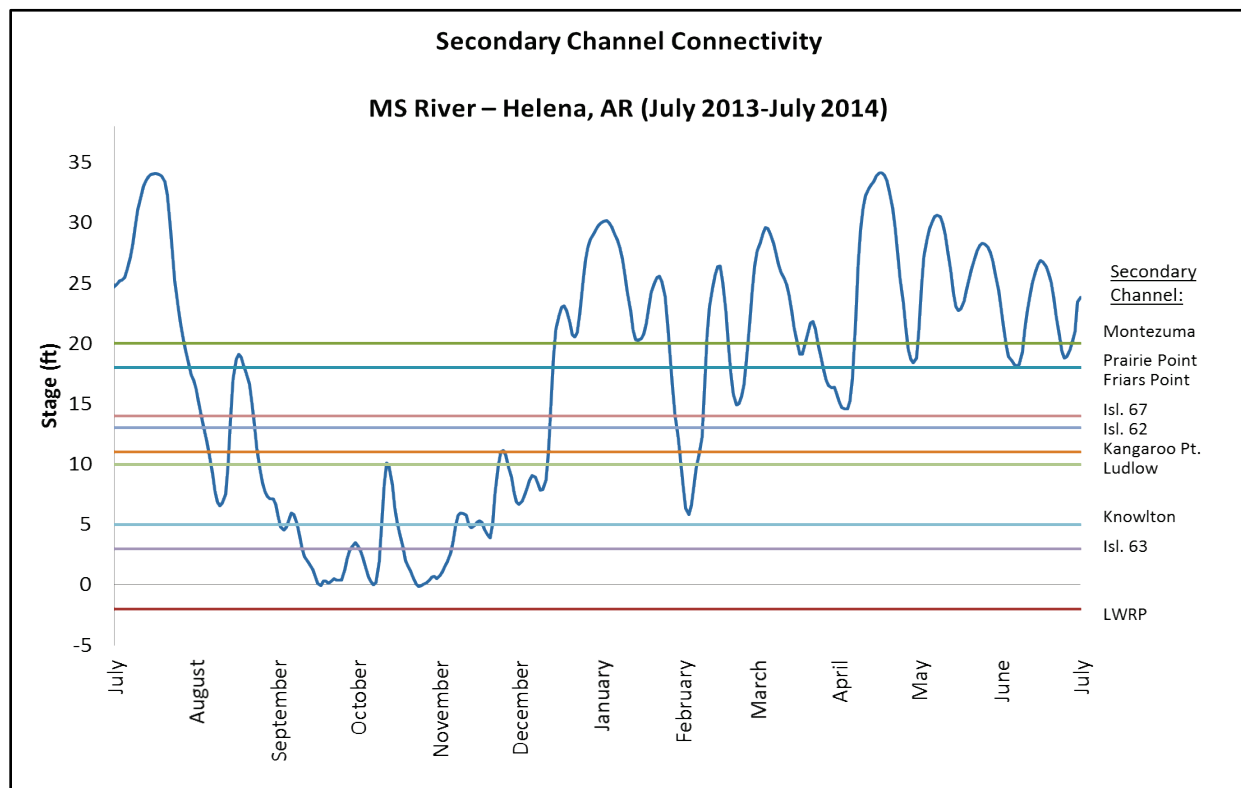


Figure 3. Mississippi River hydrograph (blue) at Helena, AR (July 2013-July 2014). Lowest river stages of disconnection, based on elevation of closure dikes, are plotted for each secondary channel studied. Historic gage data from rivergages.com. LWRP=low water reference plane (red).

RESULTS AND DISCUSSION: A total of 144 samples were taken from 9 secondary channels and 3 main channel locations in May-June 2014. Species richness was highly variable between individual samples, ranging from 0 – 18 species per sample (May and June samples). This is probably reflective of the nonuniform spatial distributions of both organisms and substrates within the secondary and main channels of the Lower Mississippi River. Catch per unit effort and species richness were higher with the benthic sled gear type (5 of 72 samples with zero catch) than with the Ponar grab (37 of 72 samples with zero catch); thus, data from May (Ponar) sampling were excluded from statistical analyses.

Among all samples, a total of 57 macroinvertebrate taxa, including insects, crustaceans (Branchiopoda, Maxillopoda, and Malacostraca), mollusks (Bivalvia), and oligochaetes were obtained. Members of the insect order Diptera were the most well-represented group across all samples (4 families), particularly the Chironomidae, which included 24 taxonomic genera. The insect order Ephemeroptera was also present in many samples and represented by eight taxonomic families, including Baetidae, Caenidae, Ephemeridae, Heptageniidae, Isonychiidae, Neophemeridae, Palingeniidae, Polymitarcyidae, and Pseudironidae. New records for the Mississippi River include: *Axarus* sp. (Diptera: Chironomidae), *Hypogasturidae* (Collembola), *Simulium* sp. (Diptera: Simuliidae), *Raptoheptagenia cruentata* (Walsh), and *Xestochironomus* sp. (Diptera: Chironomidae).



Although within each channel replicate samples were highly variable in species counts, combined species richness for each secondary channel was negatively correlated with decreased connectivity to the main river channel ($r^2=0.66$) (Figure 4). The difference in richness between the least and most connected benthic sites was 15 species. Additionally, although every secondary channel was disconnected at least once during the previous year, channels with longer flow duration supported more species-rich communities than those with longer periods of disconnection. This relationship is possibly confounded with variation in habitat heterogeneity, particularly substrate type, within each channel. Samples containing silt and mud, particularly those in highly connected channels, had the highest number of species, as well as abundance per sample (Figure 5). Samples from gravel substrates also had higher species richness than other substrates, but lower abundances (Figure 5). Sand was the most frequently encountered substrate ($n=52$, Figure 6), and comprises approximately 80% of the substrate in the Lower Mississippi River as a whole, although the lowermost reach (below New Orleans) has more silts and muds (Baker et al. 1991).

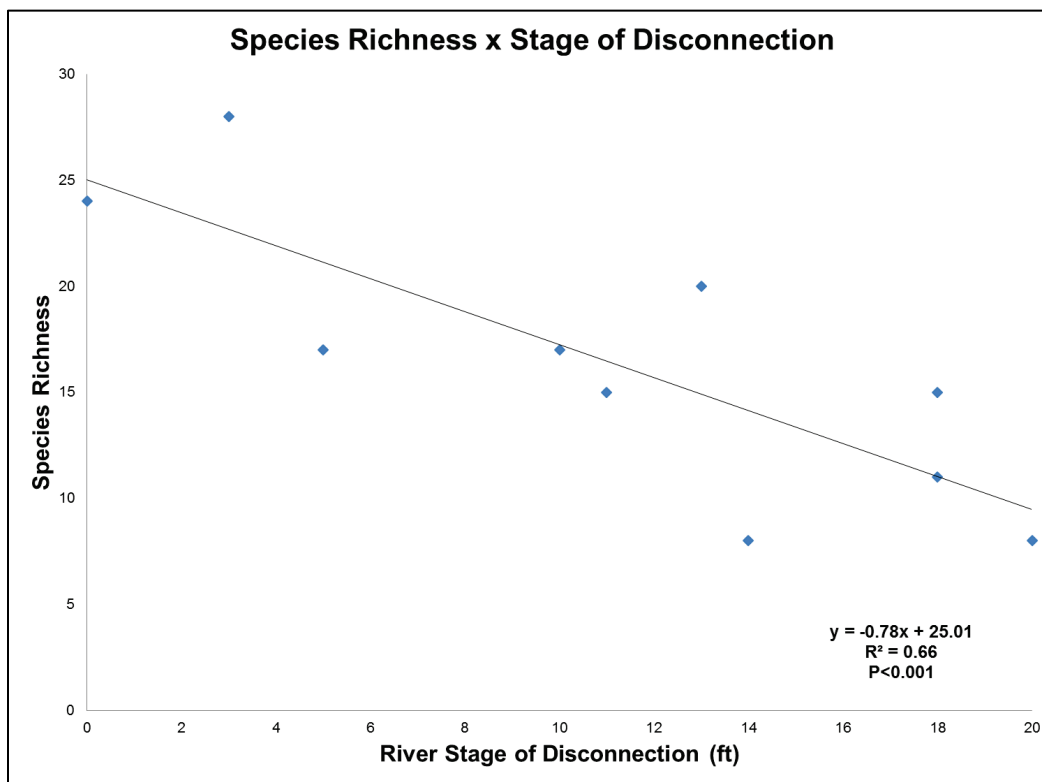


Figure 4. Linear regression ($R^2=0.66$) of combined species richness counts plotted against river stage of disconnection values (see Fig. 2) for each secondary channel. Each combined species richness count is based on six samples taken within a particular site. Main channel represents full connectivity (0 ft.); data for June (benthic sled) only.



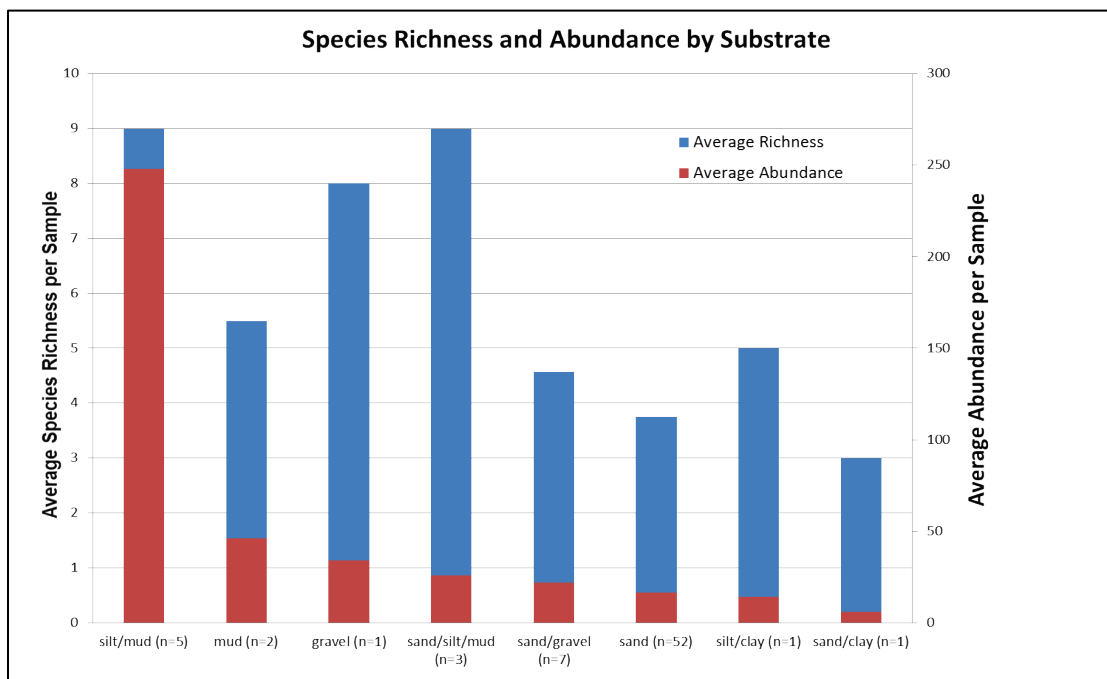


Figure 5. Average species richness and macroinvertebrate abundance per substrate among all samples (benthic sled only). The height of the red portion of each bar indicates abundance (right axis). The total height (red+blue portions) of each bar indicates richness (left axis). Substrates were classified by visual inspection at time of collection.

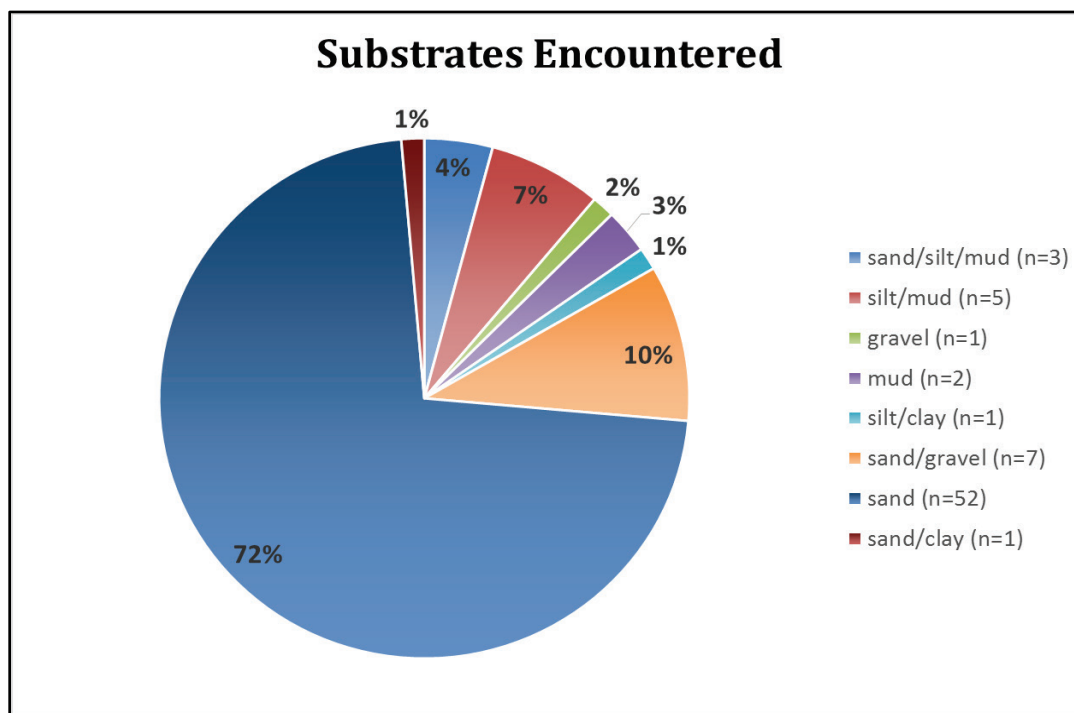


Figure 6. Substrates encountered in June sampling represented as percentages.



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Because sand is predominant in the LMR, habitats containing a variety of substrates, including silt, mud, and gravel, are of high ecological value and should be monitored and targeted for restoration efforts. The authors' study was an initial effort to evaluate how communities respond to immediate and prolonged disconnection from the main river channel. The authors now have direct evidence that greater connectivity between the main and secondary channels results in higher species richness of the invertebrate fauna. This information can be used in assessment of restoration benefits of dike notching or other programs related to increasing aquatic habitat connectivity in the Lower Mississippi floodplain.

SUMMARY: This study documented the response of benthic organisms in secondary channels of the Lower Mississippi River to varying levels of hydrologic connectivity with the main channel throughout the water year. Significant findings were the following:

- Secondary channels with longer yearly flow duration supported more species than those with shorter yearly flow duration.
- Different substrates had different levels of species diversity. Samples with silt and mud contained macroinvertebrates at higher abundances than other substrates. Greatest species richness was found in samples containing a mixture of sediments and in those with gravel.
- Five new invertebrate records for the Mississippi River include: *Axarus* sp. (Diptera: Chironomidae), Hypogasturidae (Collembola), *Simulium* sp. (Diptera: Simuliidae), *Raptoheptagenia cruentata* (Walsh), and *Xestochironomus* sp. (Diptera: Chironomidae).

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